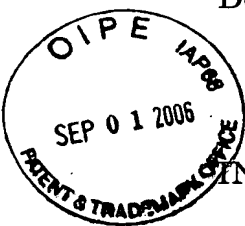Docket No.: 008312-0306969

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF: Sumio Ashida et al.

SERIAL NO: 10/717,963

FILED: November 21, 2003

FOR: PHASE-CHANGE OPTICAL RECORDING MEDIUM
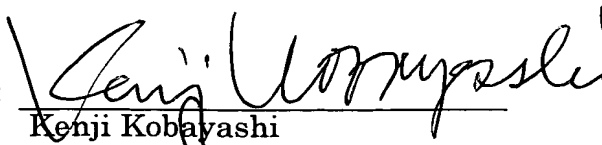
TRANSLATION OF DOCUMENT

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SIR:

Kenji Kobayashi, a translator residing at 2-46-10, Gokonishi, Matsudo-shi, Chiba-ken, Japan, hereby states:

(1) that I know well both the Japanese and English languages;

(2) that I translated the attached document identified as corresponding to Patent Application No. 2002-342896 filed in Japan on November 26, 2002 from Japanese to English;

(3) that the attached English translation is a true and accurate translation to the best of my knowledge and belief.

DATE: August 7, 2006

BY: _____
Kenji Kobayashi

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[Filing Date]   November 26, 2002

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[Title of the Invention]   PHASE-CHANGE OPTICAL RECORDING MEDIUM

[Number of Claims]   9

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    [Name of Item]   Specification   1

    [Name of Item]   Drawings   1

    [Name of Item]   Abstract   1

[Necessity of Proof]   Necessary

[Document]   SPECIFICATION

[Title of the Invention] PHASE-CHANGE OPTICAL RECORDING MEDIUM

[What is claimed is:]

[Claim 1] A phase-change optical recording medium, characterized by comprising: a semi-transparent, first information layer comprising a phase-change optical recording layer, an interface layer formed of at least one oxide selected from the group consisting of hafnium oxide and cerium oxide and formed in contact with at least one surface of the phase-change optical recording layer, a semi-transparent reflection layer, and a heat sink layer; and a second information layer formed via a resin layer on the first information layer, each stacked successively in the order mentioned on a substrate, in which heat conductivity of the heat sink layer is at least 0.7 times as high as that of the interface layer and not higher than 100 W/mK.

[Claim 2] The phase-change optical recording medium according to claim 1, characterized in that a difference between a refractive index of the resin layer and that of the heat sink layer is 0.5 or less.

[Claim 3] The phase-change optical recording medium according to claim 1 or 2, characterized in that a dielectric layer is interposed in at least one of a portion between the phase-change optical recording layer and the substrate, and a portion between the phase-change optical recording layer and the semi-transparent reflection layer.
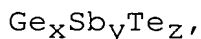
[Claim 4] A phase-change optical recording medium, characterized by comprising: a first information layer; and

a semi-transparent, second information layer comprising a heat sink layer, a semi-transparent reflection layer, a phase-change optical recording layer, and an interface layer formed of at least one oxide selected from the group consisting of hafnium oxide and cerium oxide and formed in contact with at least one surface of the phase-change optical recording layer, each stacked successively in the order mentioned on a substrate, in which heat conductivity of the heat sink layer is at least 0.7 times as high as that of the interface layer and not higher than 100 W/mK.

[Claim 5] The phase-change optical recording medium according to claim 4, characterized in that a dielectric layer is interposed between the phase-change optical recording layer and the semi-transparent reflection layer and/or formed on the phase-change optical recording layer.
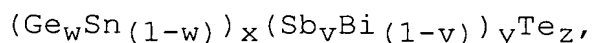
[Claim 6] The phase-change optical recording medium according to any one of claims 1 to 5, characterized in that the interface layer is formed of hafnium oxide, and the heat sink layer is formed of aluminum oxide.

[Claim 7] The phase-change optical recording medium according to any one of claims 1 to 6, characterized in that the phase-change optical recording layer is represented by the general formula:

$Ge_xSb_yTe_z$,

where $x+y+z = 100$, and a composition thereof falls within a range defined by $x = 55$ and $z = 45$; $x = 45$ and $z = 55$; $x = 20$, $y = 20$ and $z = 60$; and $x = 20$, $y = 28$ and $z = 52$ in the GeSbTe ternary phase diagram.

[Claim 8]　The phase-change optical recording medium according to claim 7, characterized in that the phase-change optical recording layer is represented by the general formula in which at least one of Bi and Sn is substituted for a part of a constituent element of the phase-change optical recording layer:

$(Ge_w Sn_{(1-w)})_x (Sb_v Bi_{(1-v)})_y Te_z$,

where x+y+z = 100, $0 \leqq w < 0.5$, and $0 \leqq v < 0.7$.

[Claim 9]　A phase-change optical recording medium, characterized by comprising: a semi-transparent, first information layer comprising a phase-change optical recording layer, an interface layer formed of hafnium oxide and formed in contact with at least one surface of the phase-change optical recording layer, a semi-transparent reflection layer, and a heat sink layer formed of aluminum oxide; and a second information layer formed via a resin layer on the first information layer, each stacked successively in the order mentioned on a substrate.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a phase-change optical recording medium in which phase change between a crystalline phase and an amorphous phase is reversibly caused by irradiation with a light beam so as to record information.

[0002]

[Prior Art]

(Principle of Phase-Change Optical Recording Medium)

The phase-change optical recording medium, comprising
a phase-change optical recording layer that permits reversible
phase change between a crystalline phase and an amorphous phase
upon irradiation with a light beam, is operated by the
principle described in the following. In a write stage,
a region irradiated with a light beam is heated to
a temperature higher than the melting point thereof so as to be
melted, followed by rapidly cooling the region to change the
arrangement of the atoms in the region into an amorphous phase.
In the erasing stage, a temperature in a region irradiated with
a light beam is maintained for at least a prescribed period of
time to fall within a temperature range from the
crystallization temperature to the melting point. Then, where
the initial state is crystalline, the crystalline phase is left
unchanged. On the other hand, where the initial state is
amorphous, the amorphous phase is crystallized. In a reading
stage, utilizing the fact that the intensity of reflected light
from the amorphous region differs from the intensity of
reflected light from the crystalline region, the intensity
changes of reflected light are converted into electric signals,
and then the converted electric signals are subjected to
analog-to-digital conversion so as to read out recorded
information.

[0003]

Incidentally, it is also possible to carry out read/write

of information by utilizing a transition between a metastable crystalline phase such as a martensite phase and a stable crystalline phase or a transition between metastable crystalline phases, in addition to the phase change between the crystalline phase and the amorphous phase.

[0004]

(Approaches to Improve Recording Density)

For increasing an amount of information that can be recorded in a single recording medium, i.e., for increasing recording capacity, it is conceivable to improve recording density by the two methods given below.

[0005]

One method for improving the recording density is to reduce a pitch of the recording marks in the track direction. However, if the degree of size reduction proceeds, a region in which the pitch of the recording marks is made smaller than the size of the read beam is arrived at, with the result that it is possible for two recording marks to be included temporarily in the read beam spot. Where the recording marks are sufficiently apart from each other, the read signals can be greatly modulated so as to make it possible to obtain signals having high amplitude. However, where the recording marks are positioned close to each other, signals having low amplitude are obtained, with the result that errors tend to be generated when the obtained signals are converted into the digital data.

[0006]

The other method of improving the recording density is to reduce a track pitch. In this method, it is possible to

increase the recording density while avoiding significant influence given by degradation in signal intensity caused by the reduction in the mark pitch noted above. However, this method gives rise to a problem of a so-called "cross-erase" that, in a region in which the track pitch is substantially equal to or smaller than the size of the light beam, data on a certain track is degraded while the adjacent track is undergoing writing or erasing.

[0007]

The cross-erase is caused by the phenomenon that the recording mark is irradiated directly with the periphery of a laser beam on the adjacent track, and the phenomenon that the heat flow in the write stage flows into the adjacent track so as to elevate the mark temperature and, thus, to degrade the shape of the mark. It is necessary to overcome these problems for increasing the recording density of the phase-change optical recording medium.

[0008]

(Approach to Achieve High-Speed Recording)

High-speed recording is another requirement for the phase-change optical recording medium. For example, where video signals can be recorded in a time shorter than an actual viewing time, it is possible to realize easily a so-called "time-shift function" which is referred to as a function of viewing previous scenes in dubbing a distributed recording medium or in writing a broadcasting program. One of the factors for inhibiting the high-speed recording in the phase-change optical recording is the problem that the data fails to

be erased completely when the crystallization is performed by a laser beam having an erase level of a relatively low power in the overwriting stage, i.e., the problem of an insufficient erasure rate. Since a recording mark passes through a laser spot at high speed, the temperature of the recording mark fails to be maintained for a sufficiently long time to fall within a range within which crystallization can be achieved, with the result that the data fails to be erased completely.

[0009]

An idea of arranging a GeN-based interface layer in contact with a phase-change optical recording layer for accelerating crystallization so as to increase the erasure rate is disclosed in Jpn. Pat. Appln. KOKAI Publication No. 11-213446. However, according to the experiments conducted by the present inventors, it has been found that, in the phase-change optical recording medium having a GeN-based interface layer, a problem is generated in the write stage. The problem is based on the phenomenon that the peripheral portion of an initially melted region in the write stage is recrystallized, and an amorphous recording mark is formed inside the recrystallized peripheral portion. To be more specific, since it is necessary to melt a larger region in order to form a recording mark of a desired size, the cross-erase is to be promoted, with a reverse effect in view of high-density recording. On the other hand, if the writing is performed with a laser power that is allowable in terms of the cross-erase, a problem is generated that the width of the recording mark to be formed is reduced so as to lower

a carrier-to-noise ratio (CNR).

[0010]

Such being the situation, it has been desired to develop a novel material for the interface layer, which permits increased crystallization speed in erasing so as to overcome the problem in terms of the insufficient erasure rate and which also makes it possible to suppress the recrystallization of the melted region in writing.

[0011]

(Increase in Recording Capacity by Dual-Layer Medium)

As another method for increasing the recording capacity, a method of superposing a plurality of information layers each containing a phase-change optical recording layer is known. The particular method is disclosed in, for example, Japanese Patent Application KOKAI Publication No. 2000-322770. It should be noted that it is necessary for the first information layer positioned close to the light incident side to ensure at least about 50% of transmittance in order to prevent the light from being superfluously attenuated in accessing to the second information layer positioned remote from the light incident side. To this end, it is necessary to reduce the thickness of the recording layer to about 5 to 8 nm and the thickness of the reflection layer to about 5 to 10 nm. Since the thickness of the recording layer is much reduced, the retention time required for the crystallization is made long, with the result that the recorded information fails to be erased completely in ordinary high-speed recording.

[0012]

As a measure for overcoming the difficulty, it is disclosed that a method of substituting Sn for a part of the GeSbTe recording layer is effective, in Proceedings of the 12th Symposium on Phase-change Optical Information Storage PCOS 2000, pp. 36-41. Also, it is disclosed that a method of substituting Bi, In, Sn or Pb for a part of the GeSbTe recording layer is effective, in Japanese Patent Application KOKAI Publication No. 2001-232941.

[0013]

Where the thickness of the recording layer exceeds 15 nm, a temperature difference is generated between the upper portion of the recording layer positioned closer to the reflection layer and cooled at a high rate and the lower portion of the recording layer. Therefore, crystal nuclei are generated on the upper portion of the recording layer and the crystal nuclei grow so as to cause the entire recording layer to be crystallized. However, where the thickness of the recording layer is small, a sufficient temperature difference is not generated between the upper and lower portions of the recording layer. Thus, it is insufficient for assuring the erasure rate to adjust the composition of the recording layer material, and it is necessary to arrange a layer producing the effect of accelerating crystallization at the interface with the recording layer. According to the Proceedings of the 12th Symposium on Phase change Optical Information Storage, it is effective to arrange, for example, a germanium nitride interface layer. However, it has been found as a result of

research conducted by the present inventors that, in the combination of a thin recording layer having a thickness of about 5 to 8 nm made of the aforementioned material and an interface layer made of, e.g., the GeN layer, degradation of read signal characteristics occurs, with the result that errors are generated frequently in converting the read signals into digital data. Particularly, the signal characteristics are prominently degraded in the case where the thickness of the GeN interface layer is smaller than about 5 nm.

[0014]

On the other hand, the reflection layer serves to cool the recording layer that has been heated by the absorption of the recording light. However, since it is necessary to decrease the thickness of the reflection layer in the semi-transparent information layer, the cooling function of the reflection layer in writing becomes insufficient, with the result that the read signal characteristics are degraded. As a measure against the difficulty, an idea of forming a heat sink layer on the reflection layer is disclosed in, for example, Jpn. Pat. Appln. KOKAI Publication No. 2000-222777. Also, it is reported that signal characteristics are improved in the case of arranging a heat sink layer having a thickness of about 100 nm and made of AlN having very high heat conductivity, in Proceedings of ISOM/ODS 2002, pp. 234-236. However, it has been found as a result of research conducted by the present inventors that recording sensitivity is degraded in the case of using a material having very high heat conductivity such as AlN for a heat sink layer.

[0015]

As described above, in the first information layer (semi-transparent information layer) of the phase-change optical recording medium having a plurality of information layers, it is necessary to make both of the recording layer and the reflection layer thinner than those of the ordinary medium. Such being the situation, it has been desired to develop an interface layer permitting a high CNR and an erasure rate while maintaining the cross-erase to a low level and to optimize the thermal characteristics of the medium including those of the interface layer and the heat sink layer.

[0016]

[Pat. Document 1]

Jpn. Pat. Appln. KOKAI Publication No. 11-213446

[0017]

[Pat. Document 2]

Jpn. Pat. Appln. KOKAI Publication No. 2000-322770

[0018]

[Non-Pat. Document 1]

Proceedings of the 12th Symposium on Phase-change Optical Information Storage PCOS 2000, pp. 36-41

[0019]

[Pat. Document 3]

Jpn. Pat. Appln. KOKAI Publication No. 2001-232941

[0020]

[Pat. Document 4]

Jpn. Pat. Appln. KOKAI Publication No. 2000-222777

[0021]

[Non-Pat. Document 2]

Proceedings of ISOM/ODS 2002, pp. 234-236

[0022]

[Object of the Invention]

An object of the present invention is to provide a phase-change optical recording medium having a plurality of information layers, which exhibits a high CNR and erasure rate while the cross-erase is maintained low.

[0023]

[Means for Achieving the Object]

A phase-change optical recording medium according to an aspect of the present invention is characterized by comprising: a semi-transparent, first information layer comprising a phase-change optical recording layer, an interface layer formed of at least one oxide selected from the group consisting of hafnium oxide and cerium oxide and formed in contact with at least one surface of the phase-change optical recording layer, a semi-transparent reflection layer, and a heat sink layer; and a second information layer formed via a resin layer on the first information layer, each stacked successively in the order mentioned on a substrate, and characterized in that heat conductivity of the heat sink layer is at least 0.7 times as high as that of the interface layer and not higher than 100 W/mK.

[0024]

A phase-change optical recording medium according to another aspect of the present invention is characterized by

comprising: a first information layer; and a second information layer comprising a heat sink layer, a semi-transparent, reflection layer, a phase-change optical recording layer, and an interface layer formed of at least one oxide selected from the group consisting of hafnium oxide and cerium oxide and formed in contact with at least one surface of the phase-change optical recording layer, each stacked successively in the order mentioned on a substrate, and characterized in that heat conductivity of the heat sink layer is at least 0.7 times as high as that of the interface layer and not higher than 100 W/mK.

[0025]

[Embodiments of the Invention]

The phase-change optical recording medium according to the embodiments of the present invention will now be described more in detail.

FIG. 1 shows a stacked structure of a phase-change optical recording medium according to one embodiment of the present invention. As shown in the drawing, on a first substrate 10, a first dielectric layer 11, a lower interface layer 12, a phase-change optical recording layer 13, an upper interface layer 14, a second dielectric layer 15, a semi-transparent reflection layer 16, and a heat sink layer 17 are deposited successively so as to form a first information layer (semi-transparent information layer) 100. In addition, on a second substrate 20, a reflection layer 24, a dielectric layer 23, a phase-change optical recording layer 22, and a dielectric layer 21 are deposited successively so as to form

a second information layer 200. The first substrate 10 and the second substrate 20 face each other and bonded with an UV curable resin 18 to each other with their deposition surfaces inside. The recording layers are irradiated with light incident on the first substrate 10.

[0026]

The phase-change optical recording medium according to the embodiment of the present invention includes an interface layer formed on at least one surface of the phase-change optical recording layer and containing hafnium oxide or cerium oxide. Incidentally, the expression "formed in contact with the phase-change optical recording layer" is used unless a layer not containing hafnium oxide or cerium oxide is formed intentionally between the phase-change optical recording layer and the interface layer. For example, even where a very thin oxide layer having a thickness of 1 nm or less, which is naturally formed on the surface of the phase-change optical recording layer during the deposition process, has been detected by, for example, Auger analysis, the interface layer is regarded as being formed in contact with the phase-change optical recording layer.

[0027]

In the phase-change optical recording medium according to the embodiment of the present invention, since two information layers are stacked, the first information layer on the light incident side is rendered semi-transparent to the recording light. The expression that the first information layer is "semi-transparent" means herein that the transmittance for the

recording light is 40 to 70% in the first information layer.
In order to make the first information layer semi-transparent,
it is desirable for the recording layer to have a thickness of
5 to 8 nm and for the reflection layer to have a thickness of 5
to 10 nm.

[0028]

Incidentally, the structure of the phase-change optical
recording medium according to the embodiment of the present
invention is not limited to that shown in FIG. 1. For example,
it is possible to form a plurality of dielectric layers between
the first substrate 10 and the lower interface layer 12. It is
also possible to omit the first dielectric layer 11 and the
second dielectric layer 15 and to form the upper dielectric
layer 14 alone between the phase-change optical recording layer
13 and the reflection layer 16. Further, it is possible for
the reflection layer 16 to be formed of a plurality of layers.

[0029]

Further, a thickness of the substrate or a deposition
order of the layer is not limited, and it is also possible to
apply the structure of the embodiments to a medium of a type in
which the substrate to be deposited is irradiated with light
and a medium of a type in which the formed substrate is
irradiated with light via a transparent sheet bonded thereto.
For example, it is possible to manufacture a phase-change
optical recording medium of a type in which the transparent
sheet on the light incident side is designed to be as thin as
0.1 mm by using an objective lens having a high NA of about
0.85.

[0030]

That is, in the phase-change optical recording medium according to the embodiment in which the transparent sheet is used, the reflection layer, the dielectric layer, the phase-change optical recording layer and the dielectric layer are successively deposited in the order mentioned on the substrate having a thickness of about 1.1 mm. Then, a thin layer of ultraviolet curable resin having a suitable thickness of 10 nm to 50 nm is formed by spin-coating. Further, the resin is cured under the state that a stamper for forming a groove is pressed against the resin, followed by peeling off the stamper. Subsequently, the heat sink layer, the semi-transparent reflection layer, the dielectric layer, the interface layer, the phase-change optical recording layer, the interface layer and the dielectric layer are successively deposited in the order mentioned. Still further, a thin transparent sheet having a thickness of about 0.1 mm is bonded or a resin layer having a thickness of about 0.1 mm is formed. In this fashion, it is possible to form a dual-layer recording medium conforming to a high NA of about 0.85.

[0031]

According to an aspect of the present invention, the interface layers are formed on both sides of the phase-change optical recording layer. However, it is possible to omit either one of the interface layers without deviating from the subject matter of the present invention. Also, it is possible to omit the dielectric layer, as required, so as to form the interface layer alone.

[0032]

The materials used for the phase-change optical recording medium according to the embodiment of the present invention will now be described.

[0033]

At least one material selected from the group consisting of hafnium oxide and cerium oxide is used for the interface layer.

[0034]

It is desirable to use, for example, GeSbTe for the phase-change optical recording layer. In particular, a prominent effect can be obtained in the case of using the interface layer specified in the present invention in combination with a GeSbTe phase-change optical recording layer having a composition close to a so-called pseudo-binary system, which can be represented by $(GeTe)_x(Sb_2Te_3)_y$.

[0035]

To be more specific, when a material used for the phase-change optical recording layer is represented by the general formula $Ge_xSb_yTe_z$, where x+y+z = 100, it is desirable to use a composition falling within a range defined by x = 55 and z = 45; x = 45 and z = 55; x = 20, y = 20 and z = 60; and x = 20, y = 28 and z = 52 in the GeSbTe ternary phase diagram.

[0036]

Also, for the phase-change optical recording layer, it is possible to use a material having Bi and/or Sn substituted for a part of the GeSbTe material of the composition range described above. The material referred to above is represented

by the general formula, $(Ge_wSn_{(1-w)})_x(Sb_vBi_{(1-v)})_yTe_z$, where

$x+y+z = 100$, $0 \leq w < 0.5$ and $0 \leq v < 0.7$. If the substitution

ratio w of Sn for Ge is not lower than 0.5, the crystallization

speed is rendered excessively high so as to cause the

recrystallization after melting to be prominent, resulting in

failure to form amorphous marks stably. Also, if the

substitution ratio v of Bi for Sb is not lower than 0.7, the

crystallization speed is also rendered excessively high so as

to cause the recrystallization after melting to be prominent,

resulting in failure to form amorphous marks stably. In

particular, the composition on a line segment connecting

$x = 30.8$, $y = 15.4$, $z = 53.8$ and $X = 40$, $y = 8$, $z = 52$ is

sufficient, and the conditions of $w = 0$ and $0.25 \leq v \leq 0.5$ are

preferable.

[0037]

Further, it is possible to use a recording layer material

prepared by adding traces of elements, e.g., Co, V and Ag,

other than Sn and Bi, to GeSbTe such that the effect of the

present invention is not impaired.

[0038]

As a material for the first and second dielectric layers,

used is a dielectric material which is substantially

transparent with an appropriate heat conductivity: $ZnS-SiO_2$,

SiO_2, SiO, Si-O-N, Si-N, Al_2O_3, Al-O-N, Ti_2O, Ta-N, Ta_2O_5,

Ta-O-N, Zn-O, ZnS, ZrO_2, Zr-O-N, Zr-N, Cr-O, Mo-O, W-O, V-O,

Nb-O, Ta-O, In-O, Cu-O, Sn-O and In-Sn-O, and a mixture of

these.

- 19 -

[0039]

As a material for the heat sink layer, used is a dielectric material which is substantially transparent with an appropriate heat conductivity: Al_2O_3, SiO_2, SiO, Si-O-N, Si-N, Al-O-N, TiO_2, Ta-N, Ta_2O_5, Ta-O-N, Zn-O, ZnS, ZrO_2, Zr-O-N, Zr-N, Cr-O, Mo-O, W-O, V-O, Nb-O, Ta-O, In-O, Cu-O, Sn-O and In-Sn-O, and a mixture of these.

[0040]

The present inventors have conducted recording-reproducing experiments in respect of phase-change optical recording media, in which the thickness of the phase-change optical recording layer was set at about 6 nm, and an interface layer having a thickness not larger than 5 nm was formed by using materials which are known to produce the effect of accelerating the crystallization of the phase-change optical recording layer such as germanium nitride (GeN), chromium oxide (Cr-O), silicon carbide (Si-C), and silicon nitride (Si-N) as well as hafnium oxide and cerium oxide.

[0041]

As a result, it has been found that there is a trade-off relationship that a CNR is lowered in the case of using an interface layer made of a material producing the effect of accelerating crystallization and that the effect of accelerating the crystallization is rendered poor in the case of using a material that brings about a high CNR. However, in the case of using hafnium oxide or cerium oxide for the interface layer, the degree of the trade-off is rendered particularly low so as to make it possible to obtain a high CNR

and a high effect of accelerating the crystallization.

[0042]

The mechanism of producing the particularly prominent characteristics in the case of using hafnium oxide or cerium oxide for the interface layer has not yet been clarified. However, it is considered that the bonding of hafnium or cerium with oxygen is stronger than the bonding of another metal with oxygen so as to produce the particularly prominent characteristics. It was believed in the past that, in the case of using a substance having intense bonding strength and a high hardness for the interface layer, the melted recording layer is shrunk in the medium including a thick recording layer so as to bring about a partial peeling between the recording layer and the interface layer. On the other hand, the semi-transparent information layer has a thin recording layer of 8 nm or less, and the shrinkage of the melted recording layer is small and, thus, is unlikely to be peeled off. Therefore, satisfactory characteristics can be exhibited in the case of a semi-transparent information layer even if hafnium oxide or cerium oxide having high hardness is used for the interface layer.

[0043]

It is possible to add another material to the interface layer in order to control the refractive index and/or the heat conducting characteristics while maintaining the satisfactory function of accelerating the crystallization. In the phase-change optical recording medium, the recording layer absorbs light so as to generate heat, and the heat thus generated is transmitted into the upper and lower layers so as to be cooled.

Whether the recording layer is rendered amorphous or crystallized is determined depending on the balance among the power of the irradiating recording light, the heat generation dependent on the linear velocity and the light irradiation time, the heat conductive characteristics of the upper and lower layers of the recording layer, and the crystallization speed of the recording layer. It follows that, in order to form a satisfactory recording mark and to obtain sufficient erase characteristics at a desired linear velocity, it is important to control accurately the heat conductivity in the upper and lower layers of the recording layer. In the embodiment of the present invention, it is possible to control the refractive index and the heat conductive characteristics of the interface layer by suitably selecting the type and the mixing ratio of the materials mixed with hafnium oxide or cerium oxide, with the result that the design of the structure of the medium can be markedly facilitated. It is also possible to substitute the material of an interface layer for the ZnS:SiO$_2$ dielectric layer which was considered to be indispensable in the past. In this case, it is possible to decrease the number of layer deposition processes so as to make it possible to provide a medium excellent in productivity.

[0044]

The material that can be mixed with hafnium oxide or cerium oxide for the interface layer includes, for example, AlN, Al$_2$O$_3$, SiO$_2$, SiO, Si-O-N, Si-N, Al-O-N, Si-C, TiO$_2$, Ta-N, Ta$_2$O$_5$, Ta-O-N, Zn-O, ZnS, ZrO$_2$, Zr-O-N, Zr-N, Cr-O, Mo-O, W-O, V-O, Nb-O, Ta-O, In-O, Cu-O, Sn-O and In-Sn-O. In particular,

it is desirable to mix Si-C with hafnium oxide or cerium oxide in order to maintain the mechanical strength of hafnium oxide and cerium oxide.

[0045]

The present inventors have conducted comparative experiments by using materials having various heat conductivities for the heat sink layer. As a result, it has been found that it is desirable for the heat conductivity of the heat sink layer to be at least 0.7 times as high as that of the interface layer, more preferably, to be higher than that of the interface layer, and to be not higher than about 100 W/mK. The detail description will be given below.

[0046]

FIGS. 2(a) and 2(b) schematically show, respectively, how heat conduction is carried out when a recording layer included in a semi-transparent information layer is heated by absorption of recording light. Ideally, it is desirable that the heat conduction in the perpendicular direction from the recording layer toward the reflection layer and heat sink layer be large as shown in FIG. 2(a) because it is possible in this case to suppress influences given to the recording layer in the adjacent tracks. However, where the heat conductivity of the heat sink layer is lower than that of the interface layer, the heat conduction in the in-plane direction within the interface layer is rendered prominent in addition to the heat conduction in the perpendicular direction of the recording layer, as shown in FIG. 2(b). Since the interface layer is in contact with the recording layer, if the heat conduction takes place as shown in

FIG. 2(b), thermal influences may possibly be given to the recording layer in the adjacent tracks. In other words, when data are recorded in the present track, the data that have already been recorded in the adjacent tracks are erased so as to cause cross-erase. It follows that, in order to prevent the cross-erase from being generated, the heat conductivity of the heat sink layer preferably be higher than that of the interface layer.

[0047]

On the other hand, if the heat conductivity of the heat sink layer is excessively high, recording sensitivity of the first information layer (semi-transparent information layer) is lowered. This is because, in the case of performing recording with ordinary light intensity under the condition that the heat conductivity of the heat sink layer is excessively high, the recording layer is made amorphous in the central portion of the beam where light intensity is high, while the recording layer remains crystalline in the peripheral portion of the beam where the light intensity is not so high and thus sufficient melting does not take place. In this case, in order to make the recording layer amorphous in the entire region of the light beam, it is necessary to carry out recording with light intensity higher than the ordinary light intensity. It follows that, in order to prevent the recording sensitivity of the semi-transparent information layer from being lowered, the heat conductivity of the heat sink layer is required not to be excessively high. It has been clarified as a result of experiments that it is appropriate for the heat conductivity of

the heat sink layer to be not higher than 100 W/mK.

[0048]

Incidentally, it is known to the art that the heat
conductivity of a material under a thin layer state differs
from that under a bulk state. However, if the two different
types of materials are compared in respect of the heat
conductivity under the thin layer state or under the bulk
state, the relationship between these two materials in respect
of the magnitude of the heat conductivity is substantially
independent of the state of the material. Such being the
situation, the heat conductivities referred herein represent
those under the bulk state.

[0049]

Then, optical characteristics of the optical recording
medium were calculated in order to obtain appropriate design
conditions for each of the layers included in the phase-change
optical recording medium according to the embodiment of the
present invention. To be more specific, the optical
characteristics (a refractive index and an attenuation
coefficient) as well as the thickness for the material of each
layer were set at prescribed values, and simultaneous equations
were formed in respect of the optical energy balance for every
interface based on the energy conservation law, followed by
solving the simultaneous equations. By these calculations, it
is possible to obtain reflectance and transmittance of the
entire multi-layered layer as well as absorbance of each layer.
This method is known as the matrix method, as described in, for
example, Hiroshi Kubota et al., "Wave Optics", Iwanami Shoten

Publishers, 1971. Here, the reflectance and the transmittance of the first information layer (semi-transparent information layer) were calculated on an assumption that a light beam having a wavelength of 405 nm is incident on the phase-change optical recording medium shown in FIG. 1.

[0050]

In the followings, suitable ranges of the refractive index and the thickness of each layer were examined based on the reflectance Rc when the recording layer is in a crystalline phase, the reflectance Ra when the recording layer is in an amorphous phase, the contrast (Rc - Ra)/(Rc + Ra), and the average transmittance of the recording layer under the crystalline phase or the amorphous phase. It is desirable that the change in each of Rc, Ra and the average transmittance be small even if the refractive index and the thickness of each layer are changed. Also, it is desirable that the contrast exhibits a high value when the refractive index and the thickness of each layer fall within suitable ranges.

[0051]

The present inventors have found first that it is desirable that the refractive index of the heat sink layer be close to the refractive index of a UV curable resin in contact with the heat sink layer. To be more specific, it is desirable that the difference between the refractive index of the heat sink layer and that of the UV curable resin be 0.5 or less and, more preferably, be 0.3 or less. This will now be described in detail.

[0052]

The optical constants were calculated in respect of the optical recording medium having a stacked structure in which a first dielectric layer $ZnS:SiO_2$ (a mixture of ZnS and SiO_2), a lower interface layer HfO_2, a phase-change optical recording layer GeSbTeBi, an upper interface layer HfO_2, a second dielectric layer $ZnS:SiO_2$, a reflection layer AgPdCu, a heat sink layer and a UV curable resin are formed on a first substrate. The refractive index of the heat sink layer is assumed to be n_{td}, and the refractive index of the UV curable resin, n_r. The refractive index n_r of the UV curable resin was set to 1.52. The refractive index n_{td} of the heat sink layer was set to 1.8 or 2.7.

[0053]

Graphs relating to the combinations of a thickness of the second dielectric layer ($ZnS:SiO_2$) as an x-coordinate and a thickness of the heat sink layer as a y-coordinate were prepared in respect of the first information layer (semi-transparent information layer) included in the optical recording medium using heat sink layers differing from each other in the refractive index. In a case where satisfactory optical characteristics can be obtained if the thickness of the first dielectric layer ($ZnS:SiO_2$) is set appropriately, the point corresponding to the particular combination is plotted in the graph. Incidentally, the satisfactory optical characteristics referred to above denote that the contrast of at least 0.8 and the average transmittance of at least 50% are satisfied.

[0054]

The experimental data are given in FIG. 3(a) [n_{td} = 1.8] and FIG. 3(b) [n_{td} = 2.7]. FIG. 3(a) supports that, where n_{td} is close to n_r, it is possible to obtain satisfactory optical characteristics even if the thickness of each of the second dielectric layer and the heat sink layer are changed over a considerably wide range. In particular, satisfactory optical characteristics can be obtained where the thickness of the second dielectric layer falls within a desirable range of between 5 nm and 30 nm. On the other hand, FIG. 3(b) supports that, where n_{td} widely differs from n_r, the range of the film thickness within which satisfactory optical characteristics can be obtained is considerably limited.

[0055]

The thermal characteristics of the phase-change optical recording medium are greatly dependent on not only the heat conductivity of each of the interface layer and the heat sink layer but also on the thickness of each of the layers, in particular, the thickness of the dielectric layer on the side of the reflection layer. Therefore, the fact that satisfactory optical characteristics can be obtained over a wide range of the film thickness indicates that it is possible to obtain easily both the satisfactory optical characteristics and the thermal characteristics.

[0056]

Then, changes in the optical constants of the optical recording medium caused by changes in the refractive index n_{td} and the thickness t_{td} of the heat sink layer were examined. In

this case, the optical constants were calculated in respect of the optical recording medium of a structure: $ZnS:SiO_2$ (50 nm)/HfO_2 (3 nm)/GeSbTeBi (6 nm)/HfO_2 (3 nm)/$ZnS:SiO_2$ (20 nm)/AgPdCu (6 nm)/heat sink layer/UV curable resin. The refractive index n_r of the UV curable resin was set at 1.52 or 1.8.

[0057]

The changes in the optical characteristics (Rc, Ra, contrast, average transmittance) of the first information layer (semi-transparent information layer) were calculated in accordance with the refractive index n_{td} and the thickness t_{td} of the heat sink layer where the absorption of the heat sink layer was set at 0. FIGS. 4(a) and 4(b) show the results. FIG. 4(a) shows the results of the calculations, covering the case where the refractive index n_r of the UV curable resin was set at 1.52, and FIG. 4(b) shows the results of the calculations, covering the case where the refractive index n_r of the UV curable resin was set at 1.80.

[0058]

Each of FIGS. 4(a) and 4(b) supports that, if the refractive index n_{td} of the heat sink layer is close to the refractive index n_r of the UV curable resin, the changes in the optical characteristics of the semi-transparent information layer caused by the changes in the thickness t_{td} of the heat sink layer is small, i.e, the distribution of the contour lines is made sparse. In the semi-transparent information layer included in the phase-change optical recording medium according to the embodiment of the present invention, the cooling effect

produced by the heat sink layer is much higher than that produced by the reflection layer or the dielectric layer. As a result, the cooling effect of the entire semi-transparent information layer is greatly changed by the thickness t_{td} of the heat sink layer. FIGS. 4(a) and 4(b) imply that, if n_{td} is close to n_r, the optical characteristics of the semi-transparent information layer are scarcely changed even if the thickness t_{td} of the heat sink layer is changed in an attempt to optimize the cooling effect of the entire semi-transparent information layer. This is a very great advantage in terms of the thermal design.

[0059]

The results given in FIGS. 3 and 4, support that it is desirable the value of $|n_{td} - n_r|$ be smaller than 0.5, in particular, it is more desirable that a relationship $n_r < n_{td} < n_r + 0.3$ be satisfied.

[0060]

Then, changes in the optical constants of the optical recording medium caused by changes in the thicknesses t_{d1} and t_{d2} of the first and second dielectric layers were examined. In this case, the optical constants were calculated in respect of the optical recording medium of the structure: $ZnS:SiO_2$ (x nm)/HfO_2 (3 nm)/GeSbTeBi (6 nm)/HfO_2 (3 nm)/$ZnS:SiO_2$ (y nm)/AgPdCu (6 nm)/SiO_2 or TiO_2 (30 nm)/UV curable resin. The refractive index n_r of the UV curable resin was set at 1.52. The refractive index n_{td} of the heat sink layer was about 1.5 for SiO_2 and about 2.9 for TiO_2. FIGS. 5(a) and 5(b) show the results. FIG. 5(a) shows the results of the

calculations in the case where SiO_2 was used for the heat sink layer, and FIG. 5(b) shows the results of the calculations in the case where TiO_2 was used for the heat sink layer.

[0061]

As shown in FIG. 5(a), where the refractive index n_{td} of the heat sink layer is close to the refractive index n_r of the UV curable resin, the changes in the optical characteristics of the first information layer (semi-transparent information layer) is relative small, i.e., the distribution of the contour lines is made sparse, even if the thicknesses t_{d1}, t_{d2} of the first and second dielectric layers on the upper and lower sides of the recording layer are much changed. On the other hand, FIG. 5(b) shows that, in the case where the refractive index n_{td} of the heat sink layer is much different from the refractive index n_r of the UV curable resin, the optical characteristics of the first information layer (semi-transparent information layer) is greatly changed, i.e., the distribution of the contour lines is made dense, even if the thicknesses t_{d1}, t_{d2} of the first and second dielectric layers on the upper and lower sides of the recording layer are slightly changed.

[0062]

Like the thickness of the heat sink layer, the thickness of each of the first and second dielectric layers on the upper and lower sides of the recording layer greatly affects the cooling effect of the first information layer (semi-transparent information layer). Therefore, the fact that the optical characteristics of the first information layer

(semi-transparent information layer) are not greatly dependent
on the thickness of the dielectric layers as shown in FIG. 5(a)
provides a significant advantage in optimizing the cooling
effect and in avoiding the changes in the characteristics
caused by the unevenness of film thickness induced in the
deposition process.

[0063]

Then, changes in the optical characteristics of the
optical recording medium caused by changes in the thicknesses
t_{d1} and t_{d2} of the first and second dielectric layers were
examined as described above, using cerium oxide in place of
hafnium oxide for the interface layer. The optical constants
were calculated in respect of the optical recording medium of
the structure: $ZnS:SiO_2$ (x nm)/CeO_2 (3 nm)/GeSbTeBi (6 nm)/CeO_2
(3 nm)/$ZnS:SiO_2$ (y nm)/AgPdCu (6 nm)/SiO_2 or TiO_2 (30 nm)/UV
curable resin. FIGS. 6(a) and 6(b) show the results.
FIG. 6(a) shows the results of the calculations in the case
where SiO_2 (refractive index: about 1.5) was used for the heat
sink layer, and FIG. 6(b) shows the results of the calculations
in the case where TiO_2 (refractive index: about 2.9) was used
for the heat sink layer.

[0064]

Like FIGS. 5(a) and 5(b), FIGS. 6(a) and 6(b) also
support that optical characteristics can be obtained over
a wide range of the film thicknesses if the refractive index
n_{td} of the heat sink layer is close to the refractive index n_r
of the UV curable resin.

[0065]

[Examples]

In the following examples, dual-layer single-sided phase-change optical recording media as shown in FIG. 1 were prepared. A 0.6 mm-thick polycarbonate substrate, formed by injection molding, was used as the substrate. Grooves were formed on the polycarbonate substrate with a groove pitch of 0.74 μm. Therefore, in the case of land and groove recording, the track pitch comes to 0.37 μm.

[0066]

Various layers were successively deposited using a sputtering apparatus on that surface of the polycarbonate substrate on which the grooves were formed so as to form a first information layer (semi-transparent information layer). A so-called cluster type sputtering apparatus, in which each layer is deposited in a different chamber, was used. Since the sputtering apparatus was provided with a vacuum transfer chamber, the substrate was transferred under vacuum until deposition processes of all the layers were completed.

[0067]

A stacked structure of Ag alloy/ZnS:SiO$_2$/GeSbTe recording layer/ZnS:SiO$_2$ was formed by sputtering on the surface of another 0.6 mm-thick substrate so as to prepare a second information layer. The recording layer of the second information layer was entirely subjected to initial crystallization using an initializing apparatus. The substrates were arranged in a manner that the first and second information layers face each other with their deposition

surfaces inside and were bonded with a UV curable resin.

[0068]

The dual-layer single-sided phase-change optical recording medium thus obtained was mounted to an initializing apparatus so as to crystallize the recording layer of the first information layer on the entire surface thereof. Then, the phase-change optical recording medium was evaluated by using a disk evaluating apparatus DDU-1000 manufactured by Pulstec Industrial Co., Ltd. The apparatus was equipped with a blue-violet semiconductor laser having a wavelength of 405 nm and an objective lens of NA = 0.65. Experiments by the land and groove recording were carried out for the phase-change optical recording medium by focusing the pick-up head of the evaluation apparatus on the first information layer. In the land and groove recording, the track pitch becomes 0.37 μm as described above. The linear velocity of the disk was set at 6.7 m/s. In the following description, the 2T mark has a mark length of 0.21 μm, and the 9T mark has a mark length of 0.95 μm.

[0069]

Reflectance (Rc) of the crystalline portion and reflectance (Ra) of the amorphous portion were measured. Further, an error rate of the data was evaluated by the bit error rate (BER) measurement, and read signal qualities were evaluated by analog measurements. A carrier-to-noise ratio (CNR), a DC erasure rate, and cross-erase (X-E) were determined by the analog measurements. Each of the measurements was performed in respect of the tracks on the groove (G) and the land (L).

[0070]

The BER measurement was carried out as follows. First,
a mark train containing marks of 2T to 9T at random was
overwritten 10 times in a target track. Then, the same random
pattern was overwritten 10 times in each of the adjacent tracks
on both sides of the target track, followed by measuring the
BER on the target track.

[0071]

The analog measurements were carried out as follows.
First, a mark train containing marks of 2T to 9T at random was
overwritten 10 times in a target track. Then, a 9T mark train
(single pattern) was overwritten once in the target track. The
carrier-to-noise ratio (CNR) of the signal frequency of the 9T
marks was measured with a spectrum analyzer. Then, the target
track was irradiated with a laser beam at an erasing power
level during one rotation of the disc as to erase the recording
marks, followed by determining decrease in the signal level of
the 9T marks. This is defined as a DC erasure rate. Also, the
head was moved to a sufficiently remote track, and cross-erase
(X-E) measurement was carried out as follows. First, a 2T mark
train was overwritten 10 times in a target track, followed by
measuring the signal level of the 2T marks with a spectrum
analyzer. Then, a 9T mark train was overwritten 10 times in
each of the adjacent tracks on both sides of the target track.
Thereafter, the head was brought back to the target track where
the 2T mark train was written so as to measure again the signal
level of the 2T marks. The decrease in the signal level of the
2T marks relative to the level measured first was defined as

the cross-erase value.

[0072]

Example A:

On the first substrate, in the film thickness shown in Table 1, ZnS:SiO$_2$ (the first dielectric layer)/HfO$_2$ (the lower interface layer)/GeSbTe (the phase-change optical recording layer)/HfO$_2$ (the upper interface layer)/SiO$_2$ (the second dielectric layer)/Ag alloy (the semi-transparent reflection layer)/SiO$_2$ (the heat sink layer) were successively deposited in the order mentioned so as to form a first information layer (semi-transparent information layer).

[0073]

The phase-change optical recording layer was formed using a target having a composition of Ge$_{40}$Sb$_8$Te$_{52}$ (Ge : Sb : Te = 10 : 2 : 13). The interference layer of ZnS:SiO$_2$ was formed using a target containing 80 at.% of ZnS and 20 at.% of SiO$_2$.

[0074]

The refractive index of the UV curable resin was about 1.5 and the refractive index of SiO$_2$ heat sink layer was about 1.5 for recording light having a wavelength of 405 nm. Also, the heat conductivity of the HfO$_2$ interface layer was 1.8 W/mK and the heat conductivity of the SiO$_2$ heat sink layer was 1.3 W/mK.

[0075]

Table 1 shows the measurement results in respect of the phase-change optical recording medium thus fabricated. The bit error rate (BER) was not higher than 6×10^{-5} for each of the

land and the groove, and thus there was no practical problem.
It is considered that the excellent BER can be obtained because
the phase-change optical recording medium exhibited excellent
characteristics in the analog measurements such that the CNR
was not lower than 52 dB for each of the land and the groove,
the erasure rate was not higher than -25 dB, and the cross-
erase was not higher than -0.2 dB. This clearly exhibits the
feature that there is no trade-off between CNR and cross-erase
(X-E) when HfO_2 is used for the interface layer.

[0076]

Incidentally, it is desirable for each layer to have
a thickness falling within the range described below. The
first dielectric layer such as $ZnS:SiO_2$ on the light incident
side should preferably have a thickness from 30 nm to 160 nm
and a range within which desired reflectance is satisfied. The
interface layers should preferably have a thickness of 5 nm or
less. The recording layer should preferably have a thickness
falling within a range of between 5 nm and 8 nm. The second
dielectric layer positioned close to the reflection layer
should preferably have a thickness falling within a range of
between 5 nm and 30 nm. The reflection layer should preferably
have a thickness falling with a range of between 5 nm and
10 nm. The heat sink layer should preferably have a thickness
falling within a range of between 10 nm and 100 nm.

[0077]

Examples B1 and B2 (Change in Composition of Recording
Layer):

A phase-change optical recording medium (Example B1)

having the stacked structure equal to that of Example A was fabricated, except that the composition of the recording layer was changed to $Ge_{40}Sb_4Te_{52}Bi_4$ (Ge : Sb : Te : Bi = 10 : 1 : 13 : 1). Table 1 shows the evaluation results. The recording medium of Example B1 was superior in each of CNR, erasure rate and X-E compared to those of Example A.

[0078]

Similarly, a phase-change optical recording medium (Example B2) having the stacked structure equal to that of Example A was fabricated, except that the composition of the recording layer was changed to $Ge_{23}Sb_{15}Te_{54}Sn_8$ (Ge : Sb : Te : Sn = 3 : 2 : 7 : 1, the sum of Ge and Sn being 31 at.%). Table 1 shows the evaluation results. The recording medium of Example B2 was somewhat inferior in CNR compared to the recording medium of Example A, though the CNR value did not bring about a practical problem. Also, the recording medium of Example B2 was superior in each of the erasure rate and X-E compared to the recording medium of Example A.

[0079]

Example C (Change in Materials of Second Dielectric Layer and Heat Sink Layer):

The material of the second dielectric layer was changed to $ZnS:SiO_2$ and the material of the heat sink layer was changed to Al_2O_3 with respect to the recording medium of Example B1. Thus, a phase-change optical recording medium (Example C) of the following structure was fabricated: $ZnS:SiO_2/HfO_2/GeSbTeBi/HfO_2/ZnS:SiO_2/Ag$ alloy$/Al_2O_3$. The

refractive index of Al_2O_3 used for the heat sink layer is about 1.7. Table 1 shows the evaluation results. The recording medium of Example C was superior in each of CNR and erasure rate compared to those of Example B1. Also, the recording medium of Example C exhibited an X-E level that gives rise to no practical problem. Further, the recording medium of Example C exhibited the most excellent transmittance.

[0080]

[Table 1]

	Example A	Example B1	Example B2	Example C
First dielectric layer	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm
Lower interface layer	HfO$_2$ 1nm	HfO$_2$ 1nm	HfO$_2$ 1nm	HfO$_2$ 1nm
Recording layer	GeSbTe 6nm	GeSbTeBi 6nm	GeSbTeSn 6nm	GeSbTeBi 6nm
Upper interface layer	HfO$_2$ 1nm	HfO$_2$ 1nm	HfO$_2$ 1nm	HfO$_2$ 1nm
Second dielectric layer	SiO$_2$ 14nm	SiO$_2$ 14nm	SiO$_2$ 14nm	ZnS:SiO$_2$ 20nm
Semi-transparent layer	Ag alloy 6nm	Ag alloy 6nm	Ag alloy 6nm	Ag alloy 6nm
Heat sink layer	SiO$_2$ 30nm	SiO$_2$ 30nm	SiO$_2$ 30nm	Al$_2$O$_3$ 30nm
Crystalline portion reflectance	13	13.7	10.5	5.9
Amorphous portion reflectance	5.1	5.5	5	1.4
Average transmittance	45	46	47	50
BER (G)	$4.0*10^{-5}$	$9.8*10^{-6}$	$4.5*10^{-5}$	$5.1*10^{-6}$
BER (L)	$5.5*10^{-5}$	$2.3*10^{-5}$	$3.0*10^{-5}$	$2.1*10^{-5}$
CNR (G)	53	55.2	51.7	56.0
CNR (L)	52.3	54.1	52.6	54.1
DC erasure rate (G)	-26.5	-29.7	-29.6	-31.9
DC erasure rate (L)	-27	-28.2	-30.9	-31.5
X-E (G)	-0.2	-0.1	-0.3	-0.3
X-E (L)	-0.4	0	0	0

[0081]

Comparative Example A (Change in Material of Interface Layer to GeN and Cr-O):

A recording medium similar to that of Example C was fabricated in which the material of the interface layer was changed to GeN (Comparative Example A1), and another recording medium similar to that of Example C was fabricated in which the material of the interface layer was changed to Cr-O (Comparative Example A2). Table 2 shows the evaluation results. The recording medium of each of Comparative Examples A1 and A2 was markedly inferior in BER compared to the recording medium of Example C. Judging from the results of the analog measurements, the reason why the poor BER was resulted in Example A1 or A2 is ascribed to the poor X-E value in the case of the GeN interface layer, and to the poor CNR value in the case of the Cr-O interface layer.

[0082]

Incidentally, it is possible to improve either the CNR or the X-E to some extent by controlling the thickness of the interface layer even in the case of using GeN or Cr-O. However, it is impossible to improve both the CNR and the X-E simultaneously.

[0083]

Comparative Example B (No Interface Layer)

A recording medium (Comparative Example B) having the structure of $ZnS:SiO_2/GeSbTeBi/ZnS:SiO_2/Ag$ alloy/Al_2O_3 was fabricated, in which the interface layers were omitted from the disc of Example C. Table 2 shows the evaluation results. In

the recording medium of Comparative Example B, it was
impossible to measure BER. Also, the recording medium of
Comparative Example B was very poor in CNR, which reflected the
poor erasure rate in overwriting. As a result, the disk of
Comparative Example B was substantially incapable of performing
rewrite under the evaluating conditions.

[0084]

[Table 2]

	Comparative Example A1	Comparative Example A2	Comparative Example B
First dielectric layer	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm
Lower interface layer	GeN 1nm	Cr-O 2nm	None
Recording layer	GeSbTeBi 6nm	GeSbTeBi 6nm	GeSbTeBi 6nm
Upper interface layer	GeN 1nm	Cr-O 2nm	None
Second dielectric layer	ZnS:SiO$_2$ 20nm	ZnS:SiO$_2$ 20nm	ZnS:SiO$_2$ 20nm
Semi-transparent layer	Ag alloy 6nm	Ag alloy 6nm	Ag alloy 6nm
Heat sink layer	Al$_2$O$_3$ 30nm	Al$_2$O$_3$ 30nm	Al$_2$O$_3$ 30nm
Crystalline portion reflectance	5.4	5.4	6.2
Amorphous portion reflectance	1.4	1.1	1.1
Average transmittance	49	50	50
BER (G)	$1.5*10^{-5}$	$2.2*10^{-3}$	Not measurable
BER (L)	$3.1*10^{-4}$	$3.1*10^{-3}$	Not measurable
CNR (G)	52.8	44.3	37.5
CNR (L)	52.1	41.9	36.5
DC erasure rate (G)	-28.4	-24.4	-20.1
DC erasure rate (L)	-26.5	-22.5	-21.9
X-E (G)	-3.7	-0.3	-0.1
X-E (L)	-1.5	0	0

[0085]

Examples D1, D2 (Dependency on Thickness of Recording Layer):

Phase-change optical recording media differing from that of Example C in the thickness of the recording layer were fabricated. In the recording medium of Example D1, the thickness of the recording layer was decreased to 5 nm. In the recording medium of Example D2, the thickness of the recording layer was increased to 8 nm. Table 3 shows the evaluation results. In the recording medium of Example D1, the reflectance difference between the crystalline phase and the amorphous phase was not sufficiently large, with the result that the recording medium was inferior in CNR compared to Example C. The recording medium of Example D2 was excellent in each of CNR and erasure rate. However, the recording medium of Example D2 was inferior in the average transmittance compared to Example C, with the result that it was difficult to write and read data in and out of the second information layer. Thus, it has been found that it is desirable for the recording layer to have a thickness falling within a range of between 5 nm and 8 nm.

[0086]

Examples E1 and E2 (Dependency on Thickness of Reflection Layer):

Phase-change optical recording media differing from that of Example C in the thickness of the reflection layer were fabricated. In the disk of Example E1, the thickness of the reflection layer was decreased to 5 nm. In the disk of Example

E2, the thickness of the reflection layer was increased to 10 nm. Table 3 shows the evaluation results. The recording medium of Example E1 was inferior in CNR compared to Example C because the cooling effect of the reflection layer was weakened. The recording medium of Example E2 was excellent in each of CNR and erasure rate. However, the disk of Example E2 was inferior in the average transmittance compared to the recording medium of Example C, with the result that it was difficult to write and read data in and out of the second information layer. Thus, it has been found that it is desirable for the reflection layer to have a thickness falling within a range of between 5 nm and 10 nm.

[0087]

[Table 3]

	Example D1	Example D2	Example E1	Example E2
First dielectric layer	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm
Lower interface layer	HfO$_2$ 1nm	HfO$_2$ 1nm	HfO$_2$ 1nm	HfO$_2$ 1nm
Recording layer	GeSbTeBi 5nm	GeSbTeBi 8nm	GeSbTeBi 6nm	GeSbTeBi 6nm
Upper interface layer	HfO$_2$ 1nm	HfO$_2$ 1nm	HfO$_2$ 1nm	HfO$_2$ 1nm
Second dielectric layer	ZnS:SiO$_2$ 20nm	ZnS:SiO$_2$ 20nm	ZnS:SiO$_2$ 20nm	ZnS:SiO$_2$ 20nm
Semi-transparent layer	Ag alloy 6nm	Ag alloy 6nm	Ag alloy 5nm	Ag alloy 10nm
Heat sink layer	Al$_2$O$_3$ 30nm	Al$_2$O$_3$ 30nm	Al$_2$O$_3$ 30nm	Al$_2$O$_3$ 30nm
Crystalline portion reflectance	5.5	7.9	4.9	8.2
Amorphous portion reflectance	2.4	0.8	1.1	2.1
Average transmittance	52	42	52	41
BER (G)	$1.3*10^{-4}$	$6.3*10^{-6}$	$1.9*10^{-4}$	$9.6*10^{-6}$
BER (L)	$1.1*10^{-4}$	$7.8*10^{-6}$	$3.2*10^{-4}$	$5.2*10^{-6}$
CNR (G)	50.3	56.7	51.3	56.3
CNR (L)	51.2	55.8	50.3	57.2
DC erasure rate (G)	-28.1	-33.2	-27.6	-27.8
DC erasure rate (L)	-25.5	-35.1	-26.3	-29.1
X-E (G)	0	-0.7	0	-0.2
X-E (L)	0	-0.4	0	-0.3

[0088]

Example F (Combination of HfO$_2$ Interface Layer and SiO$_2$ Heat Sink Layer):

A phase-change optical recording medium (Example F) having the structure of ZnS:SiO$_2$/HfO$_2$/GeSbTeBi/HfO$_2$/ZnS:SiO$_2$/Ag alloy/SiO$_2$ was fabricated. The composition of GeSbTeBi was

equal to that for the recording medium of Example B1. Table 4 shows the evaluation results. The characteristics of the recording medium of Example F including CNR, erasure rate and X-E were found to be on the levels free from the practical problem.

[0089]

Example G (Combination of CeO_2 Interface Layer and Al_2O_3 Heat Sink Layer):

A phase-change optical recording medium (Example G) was fabricated using CeO_2 for the interface layer and Al_2O_3 for the heat sink layer, the recording medium having the structure of ZnS:SiO_2/CeO_2/GeSbTeBi/CeO_2/SiO_2/Ag alloy/Al_2O_3. The composition of GeSbTeBi was equal to that for the recording medium of Example B1. The heat conductivity of CeO_2 is 15 W/mK and the heat conductivity of Al_2O_3 is 30 W/mK. Table 4 shows the evaluation results. Since the heat conductivity of the Al_2O_3 heat sink layer is higher than that of the CeO_2 interface layer, the recording medium of Example G exhibits a high CNR and a high erasure rate so as to attain low cross-erase.

[0090]

Example H (Disc Having Interface Layer on One Surface of Recording Layer):

A phase-change optical recording medium (Example H) having the structure of ZnS:SiO_2/GeSbTeBi/CeO_2/ZnS:SiO_2/Ag alloy/Al_2O_3 was fabricated, in which the lower interface layer on the light incident side was not formed. The composition of GeSbTeBi was equal to that for the recording medium of Example B1. Table 4 shows the evaluation results. The recording

medium of Example H was high in each of CNR and erasure rate and low in cross-erase.

[0091]

Example I (Omission of Second Dielectric Layer):

A phase-change optical recording medium (Example I) having the structure of $ZnS:SiO_2/HfO_2/GeSbTeBi/HfO_2/Ag$ alloy/Al_2O_3 was fabricated, in which the second dielectric layer on the recoding layer was omitted and an interface layer was substituted for the second dielectric layer. The composition of GeSbTeBi was equal to that for the recording medium of Example C. Table 4 shows the evaluation results. The recording medium of Example I was high in each of CNR and erasure rate and low in cross-erase.

[0092]

[Table 4]

	Example F	Example G	Example H	Example I
First dielectric layer	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 50nm	ZnS:SiO$_2$ 40nm
Lower interface layer	HfO$_2$ 1nm	CeO$_2$ 3nm	None	None
Recording layer	GeSbTeBi 6nm	GeSbTeBi 6nm	GeSbTeBi 6nm	GeSbTeBi 6nm
Upper interface layer	HfO$_2$ 1nm	CeO$_2$ 3nm	CeO$_2$ 3nm	HfO$_2$ 10nm
Second dielectric layer	ZnS:SiO$_2$ 20nm	SiO$_2$ 14nm	ZnS:SiO$_2$ 18nm	None
Semi-transparent layer	Ag alloy 6nm	Ag alloy 6nm	Ag alloy 6nm	Ag alloy 8nm
Heat sink layer	SiO$_2$ 30nm	Al$_2$O$_3$ 30nm	Al$_2$O$_3$ 30nm	Al$_2$O$_3$ 30nm
Crystalline portion reflectance	6.1	13.2	6.7	6.1
Amorphous portion reflectance	1.2	4.6	1.3	1.1
Average transmittance	50	46	49	50
BER (G)	$1.3*10^{-5}$	$7.3*10^{-5}$	$9.5*10^{-6}$	$8.8*10^{-5}$
BER (L)	$7.3*10^{-5}$	$7.8*10^{-5}$	$1.0*10^{-5}$	$1.8*10^{-4}$
CNR (G)	54.0	52.3	55.6	53.2
CNR (L)	52.0	52.1	54.4	51.5
DC erasure rate (G)	-33.4	-33.1	-28.7	-30.1
DC erasure rate (L)	-32.0	-31.6	-27.7	-29.8
X-E (G)	-0.1	-0.4	0	0.1
X-E (L)	-0.2	0	0	0.3

[0093]

Comparative Example C (Heat Sink Layer having Low Heat conductivity):

A recording medium (Comparative Example C) having the structure of ZnS:SiO$_2$/CeO$_2$/GeSbTeBi/CeO$_2$/SiO$_2$/Ag alloy/SiO$_2$, in which the material of the heat sink layer in the recording

medium of Example G was changed to SiO_2. Table 5 shows the evaluation results. The recording medium of Comparative Example C shows high cross-erase. The reason of the high cross-erase is attributed to the fact that the heat conductivity (1.3 W/mK) of the SiO_2 heat sink layer is markedly lower than the heat conductivity (15 W/mK) of the CeO_2 interface layer.

[0094]

Comparative Example D (Heat Sink Layer having Excessively High Heat conductivity):

A recording medium (Comparative Example D) having the structure of $ZnS:SiO_2/HfO_2/GeSbTeBi/HfO_2/SiO_2/Ag$ alloy/AlN was fabricated, in which the material of the heat sink layer in the recording medium of Example B1 was changed to AlN. Table 5 shows the evaluation results. The recording medium of Comparative Example D was incapable of obtaining a sufficient CNR even under the condition of write power of 11 mW that was the maximum for the laser mounted to the evaluating apparatus. This is because excessively high heat conductivity (270 W/mK) of AlN brings about degraded recording sensitivity.

[0095]

[Table 5]

	Comparative Example C	Comparative example D
First dielectric layer	$ZnS:SiO_2$ 50nm	$ZnS:SiO_2$ 50nm
Lower interface layer	CeO_2 3nm	HfO_2 3nm
Recording layer	GeSbTeBi 6nm	GeSbTeBi 6nm
Upper interface layer	CeO_2 3nm	HfO_2 3nm
Second dielectric layer	SiO_2 14nm	SiO_2 14nm
Semi-transparent layer	Ag alloy 6nm	Ag alloy 6nm
Heat sink layer	SiO_2 30nm	AlN 30nm
Crystalline portion reflectance	13.2	15.6
Amorphous portion reflectance	5	4.9
Average transmittance	46	45
BER (G)	$1.6*10^{-4}$	Not measurable
BER (L)	$1.4*10^{-4}$	Not measurable
CNR (G)	52.9	30.4
CNR (L)	51.2	28.3
DC erasure rate (G)	-32.4	-15.5
DC erasure rate (L)	-30	-14.1
X-E (G)	-3	0
X-E (L)	0	0

[0096]

[Advantage of the Invention]

According to the present invention specifically described above, a phase-change optical recording medium having a plurality of information layers can be provided which

exhibits a high CNR and erasure rate while the cross-erase is maintained low.

[Brief Description of the Drawings]

[FIG. 1]

A view showing a dual-layer single-sided phase-change optical recording medium according to an embodiment of the present invention.

[FIG. 2]

Views each schematically showing how heat conduction is carried out from a recording layer included in a semi-transparent information layer.

[FIG. 3]

Diagrams each showing combinations of a thickness of a second dielectric layer and a thickness of a heat sink layer which brings about satisfactory optical characteristics for a semi-transparent information layer including the heat sink layer and having different refractive indices.

[FIG. 4]

Diagrams each showing optical characteristics of a semi-transparent information layer as a function of a refractive index and a thickness of a heat sink layer, the semi-transparent information layer having different refractive indices and bonded with UV curable resin.

[FIG. 5]

Diagrams each showing optical characteristics of a semi-transparent information layer, including an interface layer of HfO_2 and a heat sink layer of SiO_2 or TiO_2, respectively, as a function of a thickness of a first dielectric layer and

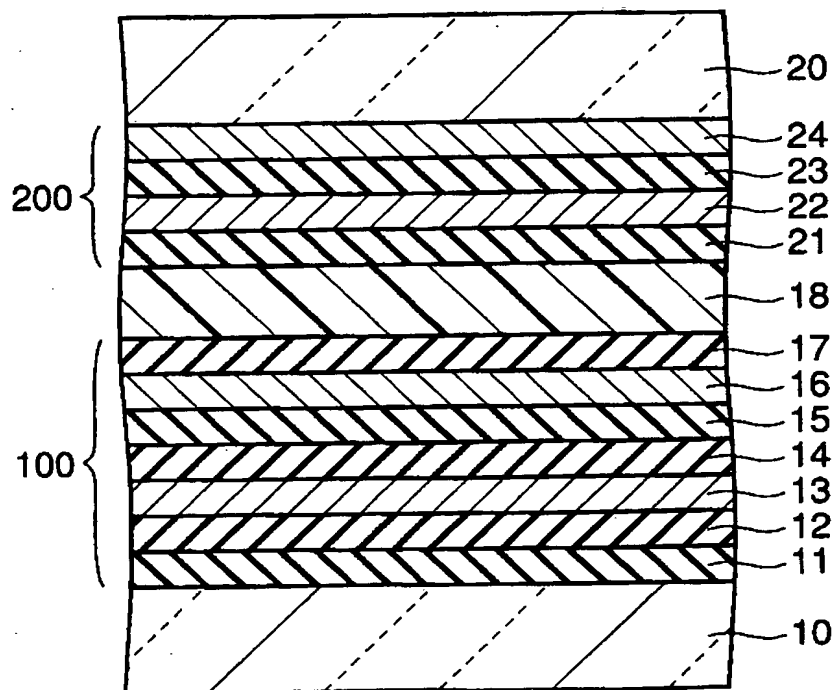a thickness of a second dielectric layer.

[FIG. 6]

Diagrams each showing optical characteristics of a semi-transparent information layer, including an interface layer of CeO_2 and a heat sink layer of SiO_2 or TiO_2, respectively, as a function of a thickness of a first dielectrice layer and a thickness of a second dielectric layer.
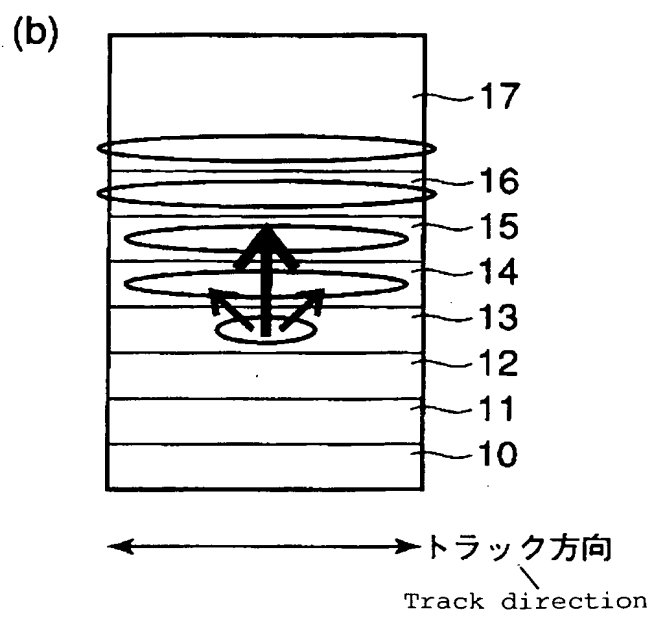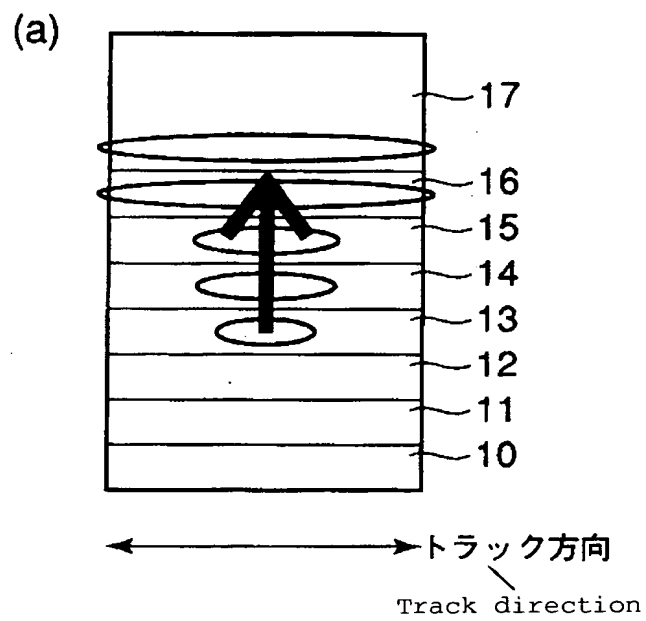
[Explanation of Reference Symbols]

10	... First substrate,
11	... First dielectric layer,
12	... Lower interface layer,
13	... Phase-change optical recording layer,
14	... Upper interface layer,
15	... Second dielectric layer,
16	... Semi-transparent reflection layer,
17	... Heat sink layer,
18	... UV curable resin,
100	... First information layer (semi-transparent information layer),
20	... Second substrate,
21, 23	... Dielectric layer,
22	... Phase-change optical recording layer,
24	... Reflection layer,
200	... Second information layer.

　　　【図1】
　　　[FIG. 1]

【図2】
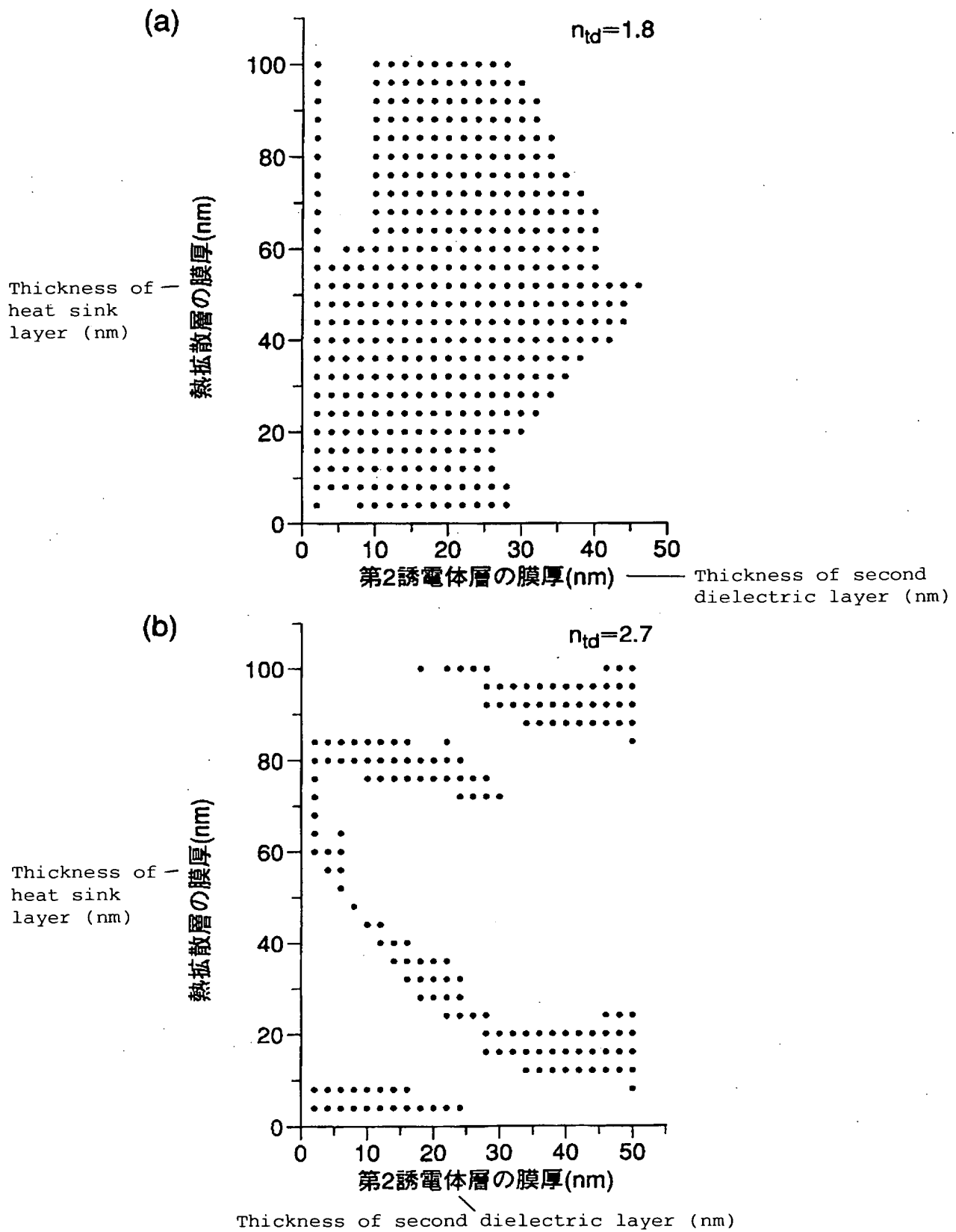[FIG. 2]

(a)

17
16
15
14
13
12
11
10

←————————→トラック方向
　　　　　　　　　Track direction

(b)

17
16
15
14
13
12
11
10

←————————→トラック方向
　　　　　　　　　Track direction

(a)

$n_{td}=1.8$

Thickness of heat sink layer (nm)

熱拡散層の膜厚(nm)

第2誘電体層の膜厚(nm) ——— Thickness of second dielectric layer (nm)

(b)

$n_{td}=2.7$

Thickness of heat sink layer (nm)

熱拡散層の膜厚(nm)

第2誘電体層の膜厚(nm)

Thickness of second dielectric layer (nm)

(a)

(b)
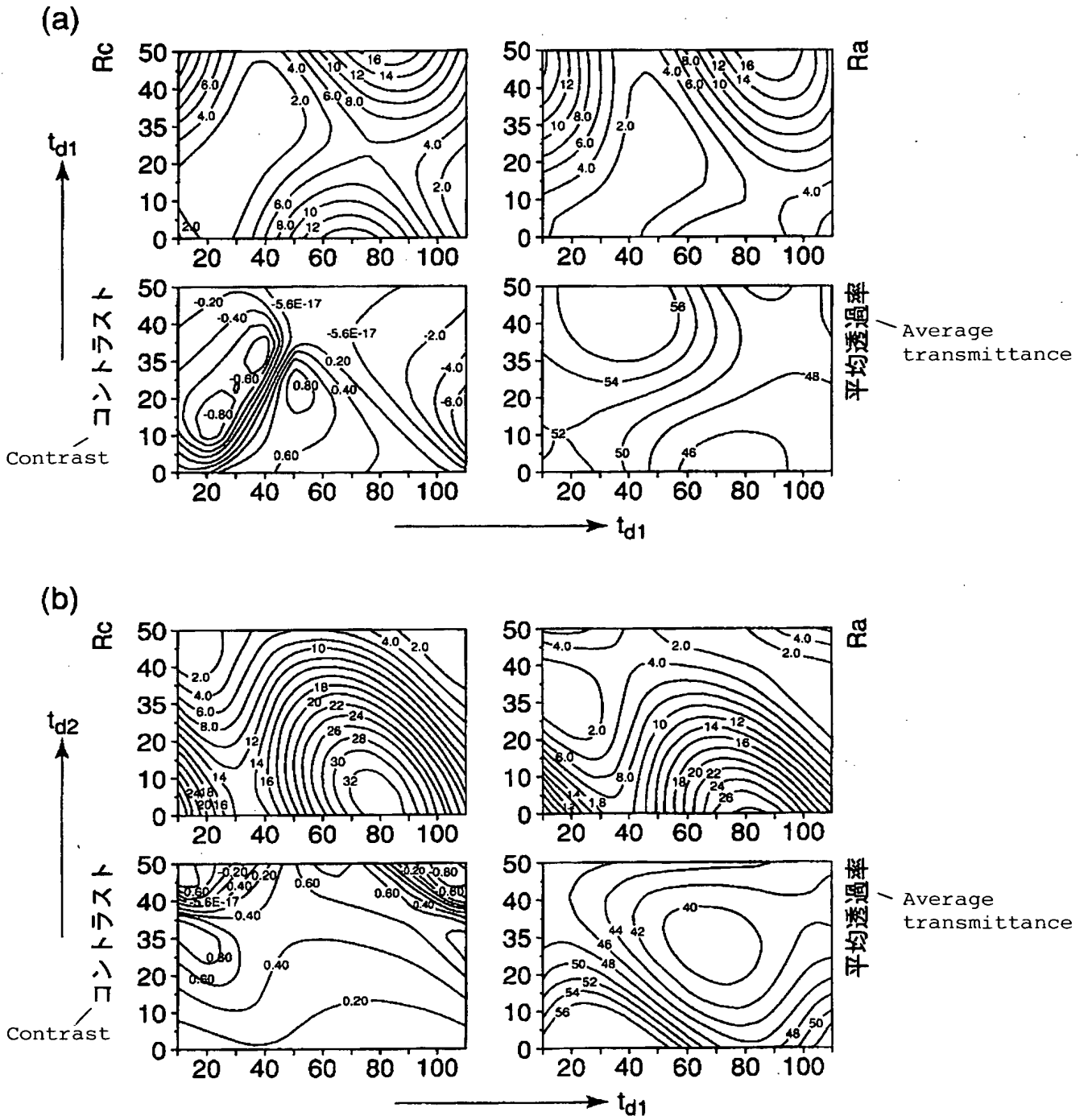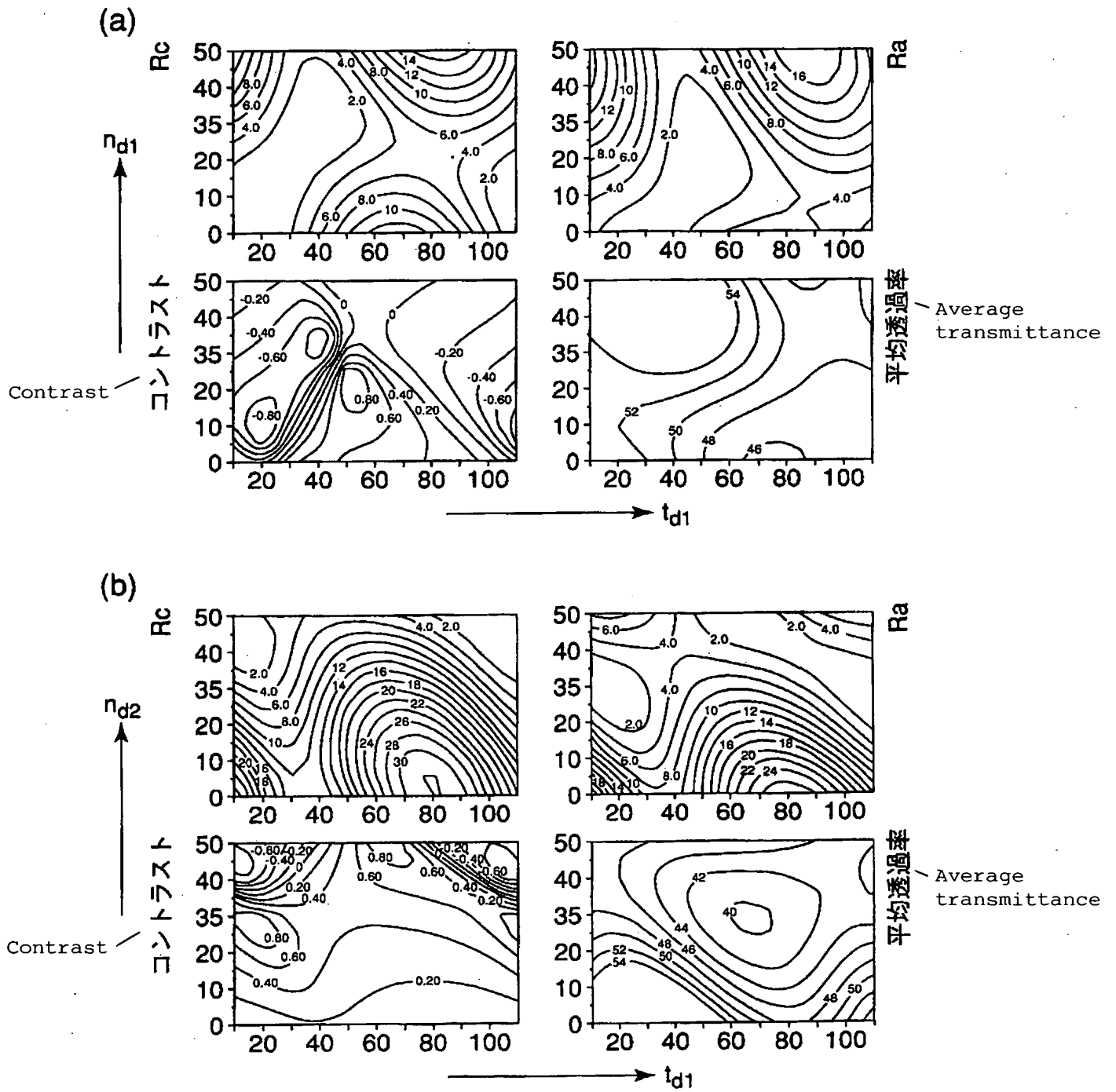
【図5】
[FIG. 5]

(a)

(b)
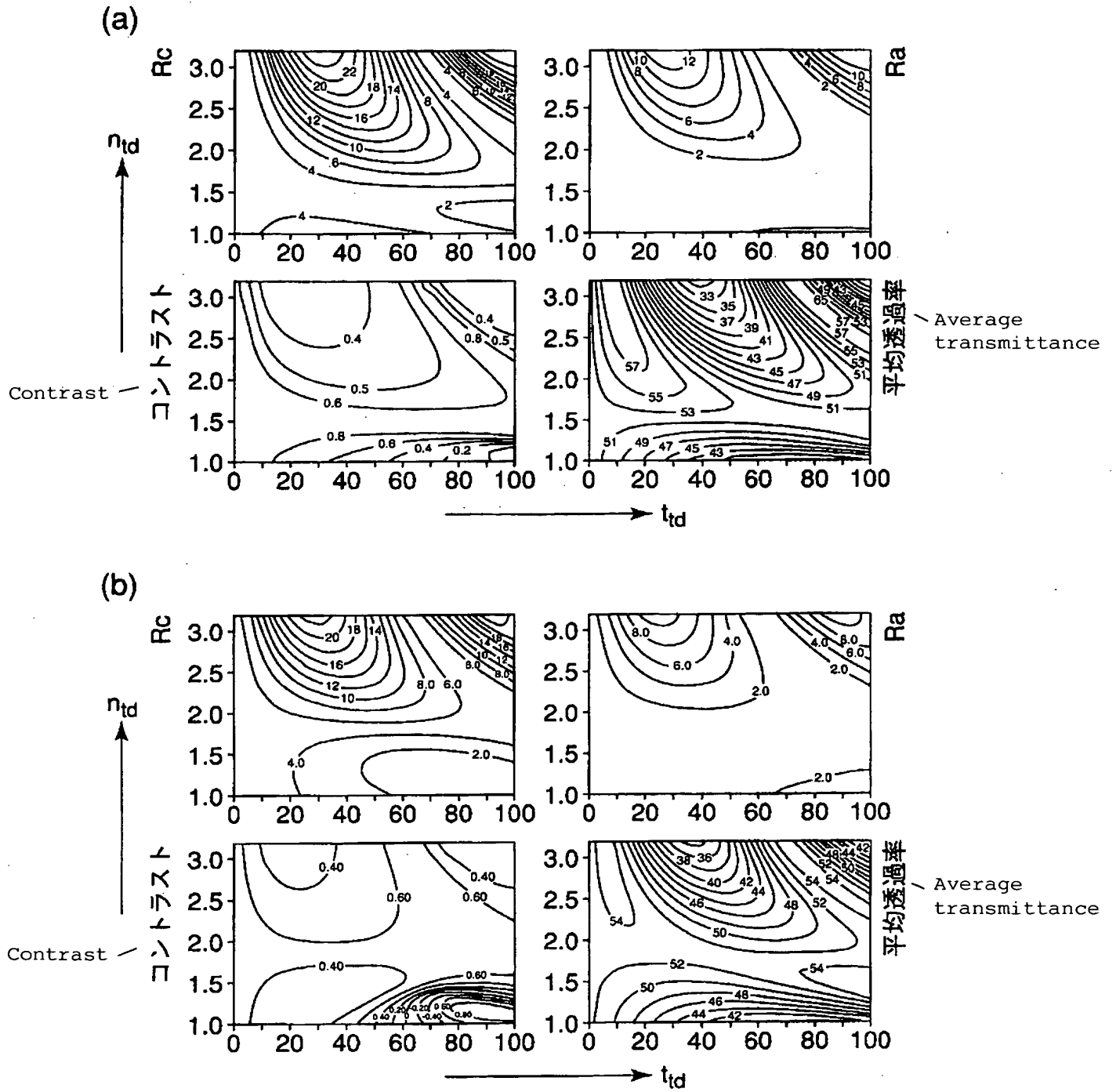
[Document]   ABSTRACT

[Abstract]

[Object] To provide a phase-change optical recording medium
having a plurality of information layers, which exhibits a high
CNR and erasure rate while the cross-erase is maintained low.
[Means for Achieving the Object] There is provided a phase-
change optical recording medium, characterized by comprising:
a semi-transparent, first information layer comprising a phase-
change optical recording layer, an interface layer formed of at
least one oxide selected from the group consisting of hafnium
oxide and cerium oxide and formed in contact with at least one
surface of the phase-change optical recording layer, a semi-
transparent reflection layer, and a heat sink layer; and
a second information layer formed via a resin layer on the
first information layer, each stacked successively in the order
mentioned on a first substrate, in which heat conductivity of
the heat sink layer is at least 0.7 times as high as that of
the interface layer and not higher than 100 W/mK.
[Elected Figure] FIG. 1